DOCUMENT RESUME

ED 260 090 TM 850 404

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TITLE Learning and Transfer Through Problem Solving and Metacognition.
PUB DATE 85
NOTE 26p.; Paper presented at the Annual Meeting of the American Eductional Research Association (69th, Chicago, IL, March 31-April 4, 1985).
PUB TYPE Reports - Research/Technical (143) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS Cognitive Style; Concept Formation; *Creative Thinking; Decision Making Skills; *Divergent Thinking; Elementary Secondary Education; Higher Education; *Learning Strategies; Mathematics Instruction; *Metacognition; *Problem Solving; *Productive Thinking; Teacher Influence; Transfer of Training

ABSTRACT

Two learning strategies are discussed: (1) fluent and creative idea-production involving concepts and problems, and (2) metacognition, or students' awareness of and direction of their thinking. The sample included college students, as well as teachers who used these strategies in elementary and secondary mathematics classrooms. Techniques for increasing flexible and original thinking were examined, along with levels of self-direction or autonomous learning. Specific problem-solving exercises are described, as well as the students' and teachers' reactions to the problems. The effects of idea production on learning, self-direction, and transfer are discussed. (GDC)

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LEARNING AND TRANSFER THROUGH PROBLEM SOLVING AND METACOGNITION

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ABSTRACT

This study describes two learning strategies: (a) fluent idea-production on concepts and problems and (b) students' direction of their thinking. Techniques for increasing flexible and original thinking are examined along with levels of self-direction. Students use the same executive strategies in school that they will use in future careers.

A sampling of student performance suggests the effects of idea production on learning, self-direction, and transfer when the proposed strategies are integrated into instruction and measures of achievement. Although the examples presented describe learning in mathematics and science, the strategies apply to all subject matter areas.

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LEARNING AND TRANSFER

THROUGH PROBLEM SOLVING AND METACOGNITION

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This study describes two learning strategies: (a) fluent idea-production on concepts and problems and (b) students' direction of their thinking. Techniques for increasing flexibile and original thinking are examined along with levels of self-direction. A sampling of student performance suggests the effects of idea production on learning, self-direction, and transfer when it is integrated into instruction and measures of achievement. Although the examples given here describe learning in mathematics and science, the strategies apply to all subject matter areas.

LEARNING AND PROBLEM SOLVING

To understand the complexity of learning, consider two levels of thinking: (a) immediate recognition or understanding and rote memory and (b) problem solving in which the identification of a problem or its solution is not immediate. At the second level, a problem is defined as an ambiguity, a challenge, or an improvement. Students meet situations in which they do not know what to do. They do not recall which algorithm to use, do not understand directions on how to use an algorithm, or they wish to identify new problems and solutions. Other challenges include activities such

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as the improvement of a business plan and the synthesis of a scientific concept. Students "learn" when they make a new connection between what is seen and what is in memory.

An important difference between levels is that in problem solving situations learners themselves connect their varied knowledge to new data, whereas in immediate cognition either someone else initiates recognition or connections are minimal. Problem situations are invitations to learn at a complex level, and depend in part upon performance at the previous level.

The more that students initiate and monitor their thinking in a problem solving mode, the more they influence their own learning. Not only should students find and solve problems that are not stated, they should also identify gaps in their knowledge and fill them. When basic skills are automatized, students can give their attention to problem solving that is an appropriate challenge. Problem solving strategies complement instruction by promoting learning autonomy and individual transfer of subject matter to new situations.

The lack of problem solving in schools is verified in the United States by the National Assessment of Educational Progress (1984) in a decline of scores on mathematical word problems and by the need for a focus on problem solving identified by the National Council of Teachers of Mathematics (1980). Concern for the development of thinking in other parts of the world is demonstrated by Venezuela and Japan, countries that offer a program of instruction on abilities such as the divergent production of ideas and the transformation of figural units.

Wirth (1983) and Pratzner (1984) call for appropriate changes

in education to integrate autonomous thinking with subject-matter development. Changes respond to challenges and opportunities that require problem solving in the environment, in economics, and in other global and local concerns. Since many facts become obsolete or at least assume different values, emerging technologies require a flexible use of basic knowledge and the production of new ideas in all roles and levels of employment.

According to recommendations made by the Association of American Medical Colleges (Fields, 1984), a passive medical education that emphasizes rote memorization and recall of facts should give way to an emphasis on independent learning and critical thinking. Strategies include increased unscheduled time, fewer lecture hours, and assignments based on problem solving. These recommendations coincide with similar requests made by leaders in business and industry.

AUTONOMY

Metacognition is the awareness and direction of thinking (Flavell, 1979; Lawson, 1984). Since metacognition has an effect on intelligence, it also influences learning (Snow, 1982). Individuals who function in an executive role over their thinking learn more and use more of what they know (Wagner & Sternberg, 1984) than those who function in a passive role. When students plan their own goals and projects, they do a greater variety of activities (Marshall & Weinstein, 1984) and vary the kinds of thinking that they do. It is assumed that training in metacognition enables capable students to choose problem-solving levels of learning.

To make problem solving and other metacognitive strategies

effective, students need to know that they are in charge of three factors: (a) access to the knowledge that they have, (b) the context of problems, and (c) their own mental abilities. First, access to knowledge reaches beyond immediate facts. Whether or not they have "learned" mathematical commutativity, for example, students who do not produce it as a possibility when it is useful do not apply it. With flexible access to stored facts and concepts, however, they use more of what they know and make multiple connections among ideas (Brown & Campione, 1981; Higgins, 1973).

Elaboration also improves the application of learned knowledge to problems (Mayer, 1970). Problem solvers who elaborate bring related ideas to consciousness. The ideas that are produced lead to solutions.

Looking for possibilities is another demonstration of access to knowledge. A habit of producing ideas for review offers alternatives to hasty conclusions. Consider the erroneous assumption that a point "between" two others on a line segment is a midpoint. Failing to check the definition of midpoint and other possible locations for the point, students often choose the familiar middle point over what appears strange.

A second area of control deals with context and transfer of learning. If problem solvers have access to "nonentrenched" knowledge, they transform what they know for use in new contexts (Sternberg, 1981). To apply subject matter learned in a specific context or in symbols, they remove specifics or attach descriptive units to symbols. Problem solvers also transform settings so that knowledge will apply to them. With enough elaboration, a more

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complex or unfamiliar context is made suitable for application of a generalization. Both conditions require that problem solvers create connections or force relationships, making a context or their own knowledge take on a new "look."

For many students, however, information is so entrenched in a format that they hesitate to apply ideas like ab + ac = a(b + c) and 5 = 2 + 3 because they "don't look right." Analyzing "□ + 2 = □ + 3," productive thinkers notice that the same variable, "x + 2 = x + 3," or different variables, "x + 2 = y + 3," might be substituted for the box. Choosing to use flexible thinking, problem solvers create options. The degree to which they use knowledge and situations in novel ways determines the degree of transfer of learning.

A third strategy for increasing autonomy is to place individuals in charge of their mental abilities. Since individual strengths and previous learning differ, students who monitor their thinking use what they know to greater advantage than those who do not. Whimbey and Lochhead (1982) recommend that students think aloud to know how they solve problems and to see where they might improve the direction of their thinking. Although teachers point out relationships and alert students to possible ambiguities, students themselves must identify contradictions and make connections with what they know.

Students should select mental operations, content, and products as well as subject matter ideas. They can select mental abilities that fit given tasks and adapt tasks to their abilities. A review of the many tasks involved in the design of a chart, for example, suggests that individuals should diagnose where they can use their

strengths and where they must develop new mental abilities. In Guilford's (1967) terms, complex chart-designing requires cognition, memory, divergent and convergent production, and evaluation of a system expressed in figural, symbolic, and semantic content. All of this is required to conceptualize the function of a chart, to classify items for it, to sequence data into a system, and to communicate it spatially.

Knowing their own mental strengths, students can also adapt tasks to their abilities. The way that one person begins to design a chart can differ from that of another person. One chart-maker begins by describing relationships in word paragraphs whereas another creates visual images in spatial arrangements to conceptualize the activity.

IDEA PRODUCTION

Divergent production is probably the most important strategy for developing problem solving (Guilford, 1967) and learning (Dirkes, 1978a) because it enables students to activate what they have learned, imagine it in varied contexts, and evaluate it. When students think erroneously or do not know what to do, they must produce ideas to change what they know or to create solutions. Students produce ideas, however, only if they choose to do so. They must choose also to produce multiple ideas, anticipating that a desirable solution will be among them. Through idea-listing, students use familiar ideas to lead to an understanding of unfamiliar concepts. A synthesis or combination of facts and ideas become concepts and problem solutions that are new to them. Rules that require fluency and outlaw criticism keep learners on task.

When students list ideas in a brainstorming format, they spend

more time thinking than if they used immediate memory and reasoning alone. Sternberg (1984) shows that more intelligent persons spend longer encoding terms of problems and planning globally whereas less intelligent persons are more likely to be impulsive and use fragmented local planning. Problem solvers know when they probe memory for ideas and select possibilities for evaluation. Often, they are so engrossed in thinking that they lose touch with the immediate environment. Then, imagination can flourish.

Inexperienced problem solvers, on the other hand, are known to minimize planning time (Steinberg, 1983). They depend on recall of items in the same way in which they were learned, and abandon thinking when memory fails. It is common to hear them remark that, "Either I know it or it don't," with little recourse to idea production and confidence in the value of their ideas.

Idea production should begin when children enter school. A teacher working with six-year-old youngsters remarked that, at first, children could not say anything about "2 + 3" other than "5." Suggesting that children who hesitated in a problem solving situation tell what they "do" know, her students began to include drawings, a comparison of addends with the sum, and other quantitative observations. When a group of ten-year-old children were asked to produce ideas for the first time, one politely inquired, "What is an idea?" She needed to produce ideas herself before she was ready to use other problem solving strategies.

Although many students who score high on standard achievement tests are likely to produce ideas fluently, some of them do not depart from a straight-forward use of definitions and rules to wider applications and to ideas that are original to themselves. A

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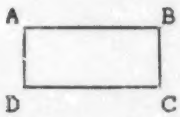
pre-calculus teacher observed that their minds are set upon following directions as if ideas are always predetermined by someone else.

Knefelkamp (1984) reports that most students enter college believing that there is a right way to find answers, the way prescribed by authority. They either graduate in the same position or advance to a role where they learn to think for themselves, knowing that authority cannot offer certainty in all situations. When students learn gradually to make significant contributions to self-initiated learning and problem solving in subject matter, they learn also to manage their performance in other circumstances of life.

Bringing ideas to consciousness requires practice. A group of teachers instructed in creative thinking were more fluent and more original than a peer group of elementary school teachers and a group of secondary school teachers who did not have the instruction (Dirkes, 1979). Without instruction, neither the number of mathematics courses taken by graduate students (Dirkes, 1979) nor one grade-level difference (Grades 5 and 6; Dirkes, 1978b) influenced idea production significantly.

Experience with groups of students in grades one through graduate school show that students must be convinced that they can "say what they think" before they will make observations and hypotheses. Moreover, they need to experience the advantage of bringing what they know and what they see to consciousness. The "obvious" is often not used unless it is named.



The lengths of AB and CD are equal or almost equal.

2 + 3 = 5

"5" is greater than "3."

Figure 1 Examples of Observations

It is necessary to tell students that whatever ideas they give will be accepted as possibilities. Moreover, they should list ideas that no one else told them and that others would not even think to produce. Almost everyone knows more than they think that they know. Students need to become risk-takers who construct ideas or recall ideas that are not affirmed by someone else first. Experiences in divergent thinking helps them not only to use what they have learned, but also to move beyond what they have learned.

TESTING THROUGH IDEA PRODUCTION

"Unstructuredness" is necessary to show whether students really know how and when to use their knowledge and skills (Doyle, 1983). According to a secondary school teacher who invites students frequently to produce ideas, idea-listing demonstrates what students know and how they think in ways that conventional tests and classroom interaction do not. An open-ended format promises to have a more positive influence on teaching and learning than more "effective" tests that fail to tap the complex thinking abilities required of problem solvers (Frederiksen, 1984).

In a test format, idea lists and problem solving steps are scored for flexibility and originality. Scoring fluency is an option. The test offers an opportunity for diagnosis of connection-making and transfer as well as previous learning.

From a student's point of view, idea-listing tests validate

creative thinking because they show that teachers value it. Tests on thinking demonstrate that many false starts and probes for understanding are useful parts of the problem solving process. Even when students produce solutions directly, they should be able to think beyond them to foster invention and transfer of learning.

Meeker (1982) recommends that students practice divergent thinking to relieve anxiety. Whether they use idea production during instruction or on tests, students know that their ideas need not satisfy rigid conditions and that they can use remotely related ideas as well as those that are specified by convention. They know also that persistence is expected and usually results in "better" ideas (Parnes & Meadow, 1969). Brainstorming prompts those who think slowly to take time to make connections, and encourages students with limited verbal skills to express their ideas in abbreviations, symbols, and drawings.

IDEA PRODUCTION FOR PROBLEM SOLUTIONS

When students are adept at divergent production, they are ready to use four steps that are based on the creative problem solving process (Parnes, 1981; Dirkes, 1983ab). Step 1: List facts that you know. Step 2: State what you want to do. "How might I ...?" Step 3: List many possible solutions. Step 4: Identify the facts, problem statement, and solution used. Fluency and originality without judgment are encouraged during the first three steps. In some cases, it is appropriate to state a criteria for making a choice from the list of possible solutions or representations of a solution.

The steps encourage problem solvers to determine the relevance of facts and assumptions, the choice of a problem statement, and

the value of one solution over another. The step in which an idea is listed, however, is not as important as the production of the idea. Not knowing a process or solution, students must look for new combinations of ideas or a new point of view. The scope of their search depends on constraints established by a given situation, and on their abilities to produce ideas and to reach beyond assumed constraints.

Discerning what the real problem is for each problem solver requires a production of alternative statements of problems and an evaluation that determines the best statement. Even though two students receive the same stimulus, one might choose a problem and solution that rely only on given facts whereas another might introduce related facts and assumptions from life experiences to increase the complexity of the problem. A much greater degree of autonomy is required in the latter case.

Students move gradually to new degrees of learning autonomy through levels of divergent thinking that are developed in conjunction with levels of mathematical problem solving.

LEVELS OF MATHEMATICAL PROBLEM SOLVING

1. Use brief algorithms without knowing why the steps "work."
2. Use brief algorithms with understanding.
3. Use complex algorithms, understanding concepts.
4. Debug procedures and solutions to agree with recognized algorithms and assumptions.
5. Select a problem solving strategy learned from a teacher, e.g., draw, work backwards from an estimate.
6. Use many problem solving strategies on the same problem.
7. Clarify a problem statement. Produce alternative solutions for a given problem and select a solution based on given

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conditions and degrees of rigor.

8. Introduce assumptions and conditions. Produce alternative problem statements and select one. Produce possible solutions and select one that is based on a self-designed criteria.

LEVELS OF IDEA PRODUCTION USED TO SOLVE PROBLEMS

1. Begin working on a problem by taking guesses. Choose one.

2. Make fluent idea lists that reflect the character of mathematics, e.g., number, estimates, spatial relations, applications, concepts, examples.

3. List many statements of a given problem in your own words. Select one.

4. Use the four-step creative problem solving process using only given information. Steps: Facts (Item 2), Problem Statement (Item 3), Ideas (Item 2), and Summary or Criteria for a Solution.

5. Use the four-step process introducing probable or possible new facts and assumptions.

6. Increase fluency, flexibilty, originality, and elaboration in the four-step process.

STUDENT PERFORMANCE

Data were collected for this study from three sources: (a) 46 third-year college students enrolled in the investigator's course on elementary school mathematics methods, (b) 4 teachers who had taken the investigator's graduate course in mathematics methods or creative problem solving and who implemented strategies in grades 1-12 during the first four months of the year (Teacher A Grades 1,2 city parochial school; B Gr. 6,9 city private school, chemistry; C Gr. 9-10 rural school, biology; D Gr. 9,11-12 rural school, mathematics); (c) two second-year college students (education major, age 36; business major, age 32) who were enrolled in an

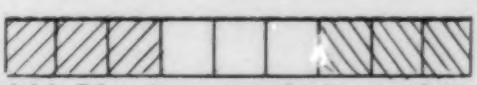
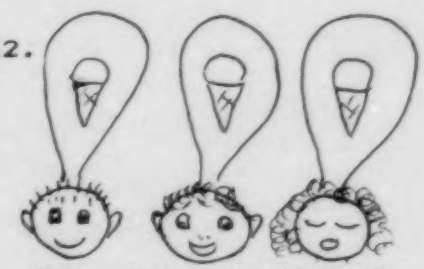
independent-study problem solving course.

Teachers were instructed to use the strategies regularly in ways that would benefit their students most. They submitted student papers and a log describing their use of strategies. No class was a group of identified gifted or handicapped students.

IDEA LISTS ON CONCEPTS

COLLEGE STUDENT Concept: division by three

The idea list was generated by one student on a test administered in a mathematics methods course.

1. Subtract 3 as many times as you can.
2. ?/3
3. What times 3 equals the number?
4. Divide a pie into 3 pieces for 3 people.
5. 3-way divider in a classroom
6. ./. 3
7. How many 3's in a certain number?
8. 
9. Add 3's in a certain number.
10. 3 lane highway
11. Put a class into groups of 3.
12. 
"de-vision by three"
13. ? x 3 = N
14. N ./. 3 = ?

In this example, the fluency score is 14 and the flexibility score is 10, indicating the number of ideas and the number of categories of ideas. Categories depend primarily on the ways that students think mathematically (Levels of Divergent Idea Production, Level 2). An item that was not discussed in class or showed an unusual depth of understanding or application is scored for originality. These ideas are listed by only one or two students in a class.

The idea lists of most students do not show the range of mathematical thinking illustrated in this example. Even here, the student did not interpret division as "three equivalent parts."

GRADE 12: Functions

Lists were made on a pre-calculus test in response to a bonus question that previewed instruction on functions.

Student A

1. Examples of functions are: f(x) = x^2-1, f(x) = x^2, f(x) = x/25
2. A function is a paring of numbers from a domain and range where each value from the domain corresponds to only one value from the range.
3. Domain: -1,0,1,2,3 Range: 0,1,2,3,4 (-1,1), (0,0), (1,1)
4. Example of a quadratic function: f(x) = 2x^2+3x-4
5. Form of a quadratic function: f(x) = Ax^2+Bx+C
6. A linear function graphs as a straight line.
7. A linear function: f(x) = 2x+1.
8. Slope-intercept form of a linear function: f(x) = mx+b

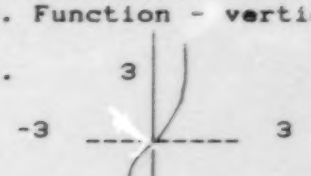
Student B

1. F(x) = x^2 is a function.
2. In a function there is a range and a domain (names of y's and x's that satisfy the equation).
3. Some functions graph as up or down parabolas.
4. Some functions graph as non-vertical lines or as S-shaped curves.
5. For each x in an equation there is one and only one y.
6. F(x) is spoken "f of x."
7. A function describes a mapping like f(x) = x+1 maps 1 into 2.
8. In one to one functions the graph crosses no horizontal line more than once.
9. f(x) = c is a constant function.

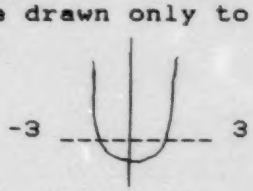
Student C

1. Domain, range, one on one, parabola, x^2 = 2(x+2)
2. One on one function so draw horizontal lines touch once.
3. S-shaped, linear function, polynomial functions
4. Function - vertical line can be drawn only to touch graph once.

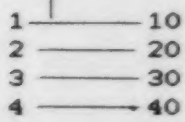
5.



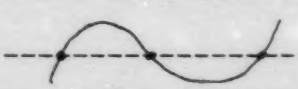
6.



7.



8. f(x) = mx + b
9. zeros of a function
10.



Note that definitions predominate. The number of categories of ideas and the optional use of graphs suggest greater variance in the understanding and use of concepts.

GRADE 9-10 BIOLOGY

The biology teacher used idea lists at least 12 times over four months in each of five classes, and administered two unit tests that each contained a section on idea listing. The second test, administered to 147 students in December, showed a correlation of .86 (least squares method) between scores for three sections in traditional formats and one idea list. Correlation between the traditional sections and flexibility scores on the list was .87. Additional data is presented in Table 1.

	Mean	S.D.	Mdn.	Range
4 Sections	210.92	59.21	209	332-95
3 Traditional sections	92.21	30.59	92	203-43
1 Idea List	118.58	42.23	112	232-52
Flexibility	13.04	4.58	12	26- 3

TABLE 1 BIOLOGY TEST

GRADE 2 Idea lists on ? + 2 = 5

Student A

```
O O + O O O  =  O O O O O
*** + ** = * *
           *
          * *
```

Student B

```
3 + 2 = 5
O O O     * * *     / / /
 O O       * *       / /
  5         5         5
```

Student C

```
this is a seven --  7
this is adding
OOOOO + OO = OOOOOOO
a plas  +
a ecwl  =
```

Student D

```
O O  +  O O O  =  5
= means equals
+ means plus
3 + 2 = 5  2 + 3 = 5
a + in it       = 7
? in it  ? 2 + = 5  ? 3 +=5
```

CREATIVE PROBLEM SOLVING

COLLEGE STUDENT Situation in which the problem was not stated on a mathematics methods test

Situation: A teacher applied for a position at a school that had six times as many boys enrolled as girls. Each class had about 30 students.

Facts: teacher applies for job
job at school
6 times as many boys as girls
each class: about 30 or less
more boys in each class

Problem: How might I decide how many boys and girls are in each class of about 30 students?

Ideas:

1) B B B B B B G B B B B B B G B B B B B B G B B B B B B G O O

24 boys and 4 girls in each class and 2 empty chairs
For every 6 boys there will be 1 girl, 6:1.
If there are 4 girls in the class, there are 6 times as many boys.
4 girls x 6 = 24 boys

2) Begin with 1 girl, 2 girls, ...

Girls	6X	Boys	=	boys and girls
1	X6	6		7
2	X6	12		14
3	X6	18		21
4	X6	24		28 nearest to 30
5	X6	30		35 over 30, can't use

3) Try to make a formula. 6 X G = B and G + B = about 30
Table for numbers that satisfy both equations:

G	B	G + B	
1	6	7	Continue as above.

Summary:

Facts: 6 times as many boys as girls. A class of about 30.
Ideas: Solution #3 is best.
Solution: 4 girls and 24 boys.

Some repetitive ideas were omitted in this example. Listing them as a testee, however, maintains a focus and mental activity that contribute to connection-making. Note that the student converted "6 times as many boys as girls" in the Facts Section to "6 x girls = boys." Listing ideas allows time for insight and corrections to emerge as one of many possible alternatives.

If the student exercised even greater control over his thinking, he might have questioned the given ratio of boys to girls

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as highly improbable. We wonder also if the assumption that the boy-girl ratio of each classroom equivalent to that of the school was a conscious one. If so, the assumption, "more boys in each class" included in the Facts Section, should be stated as a specific condition introduced to invite an alternative problem or solution. In some cases, the ease in which someone else can follow a solution becomes part of the criteria for choosing a solution, like a chart, instead of others that are written in prose.

Problems stated by other students in the group of preservice teachers included "How might I find the number of students in the school?" and "How might I decide if I will take the job?" The latter statement might have been an effort made by a student, who was uncomfortable with mathematics, to avoid a quantitative problem.

GRADE 11-12 Student assignment in an Algebra II course.

Write a story problem that requires a quadratic equation for its solution.

Problem described by a student: The width of a rectangular swimming pool is 20 meters and the length is 30 meters. We are putting a rectangular fence around our entire yard. The area of our lawn around the pool is 2 times the area of the pool. How wide must the fence around our yard be?

The student solved the problem, using the equation, $2(600) = (2x+30)(2x+20)$, in which "yard around the pool" was interpreted to include the area of the pool. Use of the four-step process and a diagram might have clarified this condition.

Although most students in the group used textbook problems as models, a few students added imaginative circumstances, e.g., King Delirious Dork's pet alligator with the formula for a falling object.

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GRADE 2 Assignment written by children in December.

Situation stated by a teacher:
Family. Largest # is 16. Smallest # is 7.

Student A

HMI (How might I) find out what the #'s are that the family is.
Ideas Wel if you have a ? you have #'s family that are 16 and 7 all you haf to know what 7 + 8 = 16 so it has to be 8.

Student B

HMI find out what the third number is. HMI find out what it equls.
Ideas 16 7 9 7 + 9 = 16 It is a sum.

Student C

HMI find out whait the thid number. HMI find out whait 16 + 7 =.
Ideas 0000000000000000 16 - 7 = 9 16 7 9

Student D

HMI find out the family. HMI find out the numbers.
7 9 16 9 + 7 = 16
////////// + /////// = ////////////////
16 - 9 = 7 16 - 7 = 9

Student E

HMI find out what the other number is.
HMI figer the third number is in the family.
Ideas it must be 9 because if it was ny other numder it wood be too low or too hiny
16 7 9

GRADE 2 Responses from nine children

A teacher stated the situation given below and wrote ideas on the chalkboard.

Situation: Twenty-three students went on a leaf hunt for ten leaves that had been picked and hidden by a teacher.

Facts: 10 leaves, 23 kids All kids want to go.
Not everyone gets a leaf. More leaves than kids.

Problem: How might we ...
find out how many kids in a group?
find out how many groups there will be?
find how many kids and how many groups?

Ideas: How might we find out how many groups there will be?

1. 2 groups of 10: XXXXXXXXXX (2 leaves) and XXXXXXXXXX (2 leaves)

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Only 4 leaves! 20 people.

2. Get in line and say one here, one over there, one here, and so on.
3. Put 5 in a group: XXXXX is 5 kids (2 leaves), XXXXX is 5 kids (2 leaves), XXXXX 5 kids (2 leaves), XXXXX 5 kids (2 leaves), OOO 3 kids (2 leaves) = 10 leaves
   It's not fair!
   5 + 5 + 5 + 5 + 3 = 23 kids
4. Get more people for the last group.
5. Take the 3 people and put them in the other big groups.
   XXXXX (2 leaves) XXXXXO (2 leaves) XXXXXO (2 leaves)
   XXXXXO (2 leaves) shows 8 leaves.
6. Give them (4 groups of 5 children) 3 leaves.
   3 + 3 + 3 + 3 = 12 leaves. Too many.

(Teacher comment, pointing to Idea #3: "If you add people to groups, can you also take away from groups?)

7. Take one from a big group and give it to the group with 3.
   XXXXX XXXXX XXXXX XXXX XOOO
   This is fair.

OBSERVATIONS MADE BY CLASSROOM TEACHERS

Gr. 9-12 Students want to give correct answers only. The older the student the less likely they are to be willing to try when they think that they might fail. The older group, however, became the best group for directing their own learning.

Gr. 9-12 Students don't mind having their errors corrected when teachers list ideas on the board without judgment. Usually a couple of other students contribute ideas before someone makes a correction, so that the person making an error is not identified easily.

Gr. 6,9 Students feel "safer" learning rules. Students with the highest grades rely more on creative problem solving than those with less interest and ability. Many students are uncomfortable with opportunities to make choices. They really need this program.

Gr. 9-10 I have more insight into what each student understands. I have never learned so much about what students know.

Gr. 9-12 I find it difficult to let students struggle. The more I ask for "what else can you say," the easier it becomes for me and the better off students are because then they are learning to solve problems. As it becomes easier for me, students seem to be more willing to guess publicly.

Gr. 9-12 At first, students didn't like to take time to write lists and work through details. Later, idea lists became second nature to some students. Others never use them outside of group sessions.

Gr. 6,9. "Can you help us get started" has worked well. Students

feel more secure if they aren't responsible for the whole load.

Gr. 9-12 A few students who would never volunteer to put a problem on the board are now willing to get the problem started for us.

Gr. 9-10 Students use idea lists to study for traditional tests. 120 out of 146 students said that they prefer brainstorming methods to tradition methods of learning and testing.

Gr. 6 One student with a learning disability was getting C's and D's until I allowed him the freedom to give an example or draw a picture for his responses. Now he has acquired a genuine enthusiasm for class participation and has even done much better on written work.

Gr. 11-12 A bonus question (idea listing at the end of a test) that previewed a concept helped me to diagnose what students needed to learn.

Gr. 2 At this age, children are naturally spontaneous. There was, however, a noticable increase in their fluency from September to December. At the end, I had children who asked to make idea lists.

Gr. 1,2 It is beneficial to use these methods in other subject matter areas. I intend to continue to work with these strategies.

Gr. 6,9 This is an exciting new tool for myself and for classroom work. I look to greater skill with continued use.

Gr. 9-12 Idea lists help me prepare lecture notes. I find them extremely helpful. I had used some of these methods before, but had not organized them.

Gr. 6,9 It helps me draw up more complete lesson plans.

OBSERVATIONS MADE BY COLLEGE STUDENTS

I look at more ideas than I normally would. One idea leads to another and another. "I'm on a roll."

Unfamiliarity is a problem until I begin to diagram and write more and more. Creative problem solving gives me a format and keeps my mind on what I am doing. I can go back and see what I did before.

There were many times I used a restatement of a problem until I finally saw what I was really looking for.

Sometimes I took days to finish a problem. That enabled me to see it differently, which helped.

I had an inferiority complex because I was not logical. These techniques gave me the freedom to think.

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CONCLUSIONS

Learning becomes a problem solving process when students encode given facts, know what they want to accomplish (problem statement), connect ideas, and integrate these steps (summary). Fluent idea production makes alternatives accessible at each step of the process. When the learning process and measures of achievement include idea listing and creative problem solving, students become aware of the need for using different kinds of thinking. Conversely, metacognition increases the degree to which students make learning and its transfer a problem solving experience. When metacognition is developed as a primary locus of control, students are aware that they can call on their own resources to fill subject matter gaps and compensate for weaknesses in mental abilities.

Examples of student idea-listing and reports from teachers show that students have a far greater capacity to produce and connect ideas than traditional instruction allows. The effects of instruction on deferred judgment and flexible idea-production are promising.

Low flexibility scores indicate that students (a) have limited knowledge, (b) do not make connections autonomously to discover knowledge, or (c) do not say what they think because they do not trust the connections that they make. With some refinement, the

scoring can provide measures of learning. Since entries made on idea lists are the concepts to which students have access, these must also be the ideas used in new situations both in school and out of it. Scoring, therefore, suggests a means for measuring transfer of learning to new contexts. Much more research needs to be done, however, to help students plan and monitor the kinds of thinking that they use, along with use of time, degree of accuracy, and other executive factors.

Since these strategies are a serious departure from most classroom experience, experimental research on an intervention program should be conducted with careful attention to the duration of the instruction and development of enough strategies to overcome current and historical factors that inhibit independent thinking. Before most students will develop attitudes that enable them to make implications and transformations freely, they must be convinced that they know much more than they bring to immediate consciousness. Secondly, they need to experience that others recognize their ideas. Then they can choose when to follow directions and when to plan and monitor their own thinking. For a valid measurement of program effectiveness, therefore, knowledge aquisition, metacognition, and creative problem solving need to be developed concurrently.

A decision to develop advanced levels of autonomous thinking is a decision to prepare students for a commitment to values and to life-long learning. When students learn in a creative problem solving mode, they improve their performance in both school and society. Managing their own thinking, they imagine, plan, and implement their dreams, and contribute to the world in ways that

only each one of them can.

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